Materials Engineering Branch

TIP*

No. 089 Effect of Cure Process on Glass Transition Temperature

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The effect of glass transition temperature (T_g) on polymer material properties is discussed in TIP 062. In addition to the information presented therein, it is equally important, to take into consideration the effect that curing conditions can have on a polymer's transition temperature and the changes that occur when a material is exposed to temperatures above that region or thermal cycled through this region.

Two-part polymer resins are normally cured at room temperature (RT), usually for 5-7 days, or at an elevated temperature to accelerate the curing reaction. Polymers that have a T_g above RT which are cured at RT normally exhibit an enthalpic relaxation when the material is first heated above its T_g. This enthalpic relaxation is caused by internal molecular stresses being relieved as the polymer passes through its T_g. This stress relieving can affect the properties of the polymer, such as, a lower T_g than originally expected with the cured polymer and wild fluctuations of the coefficient of thermal expansion (CTE) through this region. Figure 1 shows a thermal expansion plot of a typical epoxy. One curve is the material after a RT cure, while the second is the same material after a post cure at a temperature above its T_g. Note the smoother T_g region in the post-cured sample. Although these internal stresses are significantly relieved during the initial heating through the T_g, several passes through the T_g region may be necessary to eliminate the stresses. In order to eliminate the stresses, a post cure of the material at a temperature above its T_g is recommended.

Another effect that post curing and thermal cycling may have on the polymer is that the post cure and each thermal cycle may shift the T_g to a higher temperature region. This may allow the end user to "tailor" or adjust the polymer's T_g to a more desirable region. Figure 2 shows the shift of the T_g for a typical epoxy after repeated thermal cycles above its T_g region.

Since each polymer and its application are different, the effect of post curing and thermal cycling on the polymer's properties should be evaluated individually before implementation in a production program. Various thermal analysis instrumentation, such as, differential scanning calorimetry (DSC), thermo mechanical analysis (TMA), and Dynamic Mechanical Analysis (DMA) can be used to evaluate these effects. It is important to consider not only a polymer's Tg, but also the effect processing has on its properties, including the Tg. Changes in processing conditions can change unforeseen and seemingly unrelated properties.

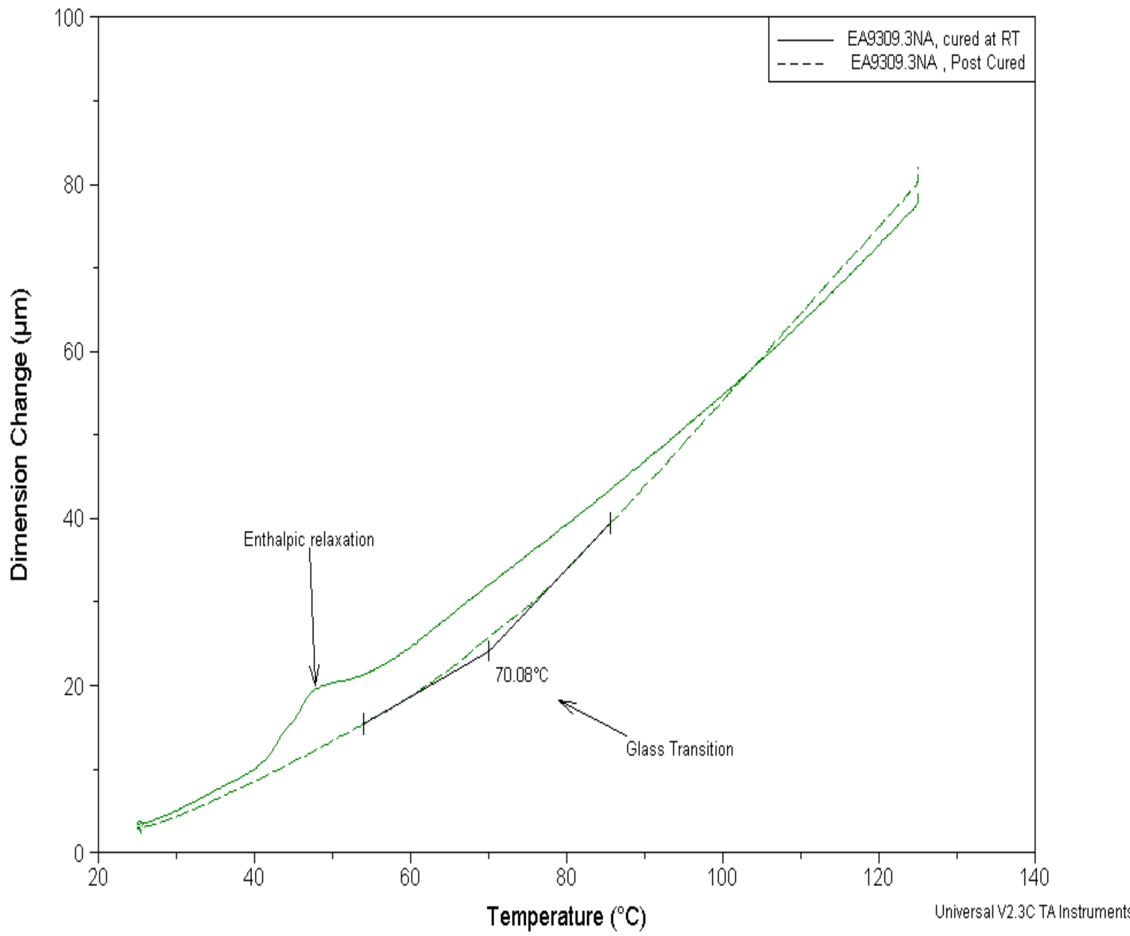

Figure 1. TMA plot showing thermal expansion data from EA9309.3NA Epoxies. One sample was cured at RT for 7 days and the other sample was cured at RT for 7 days + post cure at 125°C.

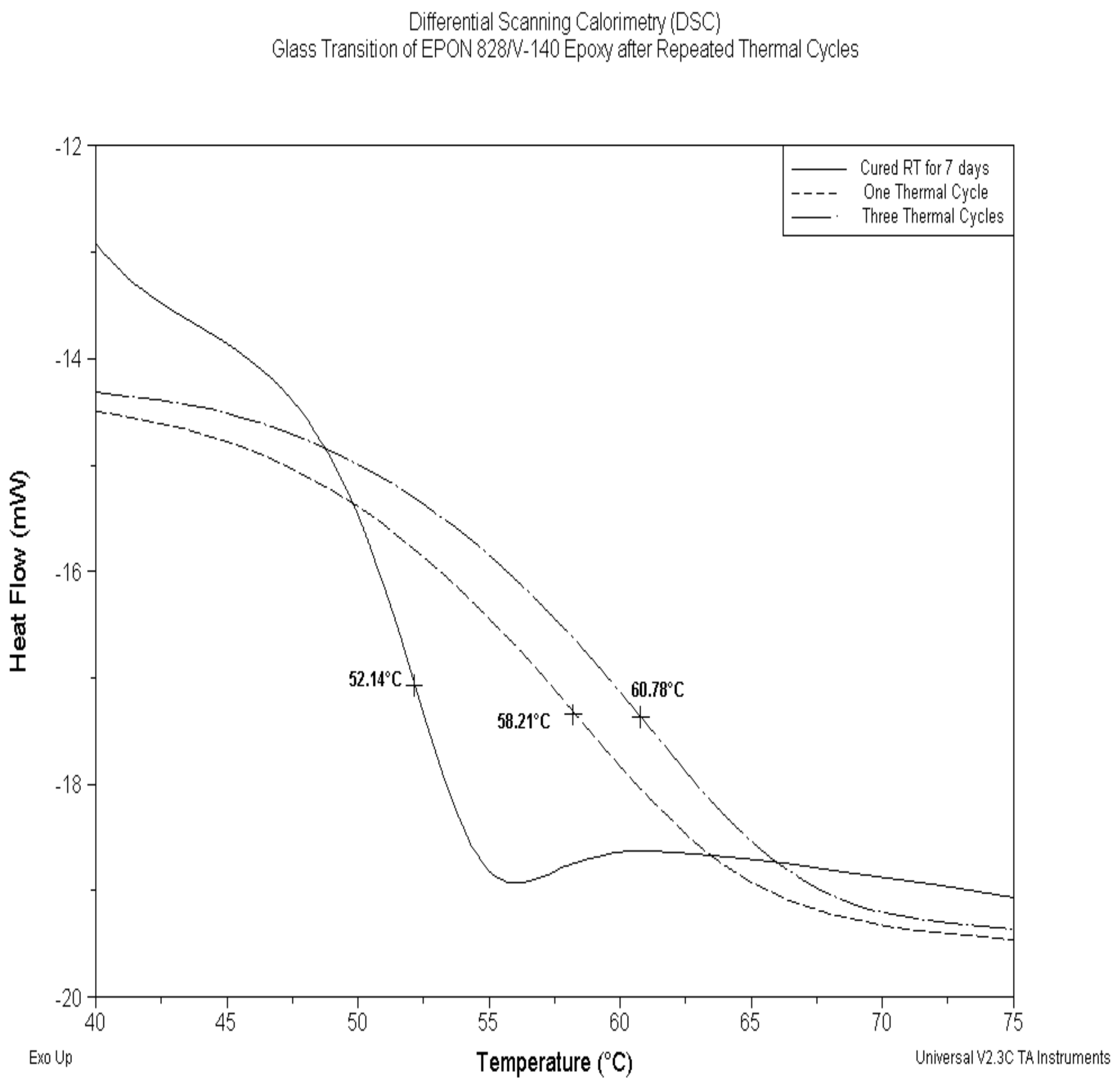

Figure 2. Illustration of the shift in glass transition temperature of an epoxy resulting from thermal cycling above the T_g compared to a room temperature cure.